TECHNICAL REPORT

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INFRARED ALGORITHM DEVELOPMENT FOR OCEAN OBSERVATIONS WITH EOS/MODIS

Abstract

Efforts continue under this contract to develop algorithms for the computation of sea surface temperature (SST) from MODIS infrared retrievals. This effort includes radiative transfer modeling, comparison of *in situ* and satellite observations, development and evaluation of processing and networking methodologies for algorithm computation and data accession, evaluation of surface validation approaches for IR radiances, and participation in MODIS (project) related activities. Activities in this contract period have focused on radiative transfer modeling, evaluation of atmospheric correction methodologies, analysis of field data, objective analysis approaches, revision of the ATBD and participation in the ATBD review process, and participation in MODIS meetings.

MODIS INFRARED ALGORITHM DEVELOPMENT

A. Near Term Objectives

A.1. Continue algorithmic development efforts based on experimental match-up databases and radiative transfer models.

A.2. Continue interaction with the MODIS Instrument Team through meetings and electronic communications, and provide support for MCST pre-launch calibration activities.

A.3 Continue evaluation of different approaches for global SST data assimilation and work on statistically based objective analysis approaches.

A.4 Continue evaluation of high-speed network interconnection technologies.

A.5 Continue evaluation of various *in situ* validation approaches for the MODIS IR bands.

A.6 Provide investigator and staff support for the preceding items.

B. Overview of Current Progress

B.1 January-March 1997

Activities during the past three months have continued on the previously initiated tasks. There have been specific continuing efforts in the areas of (a) radiative transfer modeling, (b) generation of model based retrieval algorithms, (c) continued work on IR calibration/validation as part of the MODIS Ocean Science Team cruise effort, d) analysis of consequences of imperfect pre-launch characterization of the MODIS infrared channels, and (e) test and evaluation of an experimental wide area network based on ATM technology. In addition previously initiated activities such as team related activities continue.

Special foci during this three month period have been:

1) AVHRR *in situ* comparison data base studies.
2) Continue analysis of measurements from the DOE/NOAA/NASA ARM Combined Sensor Project cruise in the Tropical Western Pacific in the spring of 1996.
3) Construction of a marine FTIR instrument for cal/val applications by UW/SSEC via subcontract .
4) Negotiate for ship-time for post-launch validation, and explore options for long-term validation for fixed platforms.

B.1.1 Radiative Transfer Modeling

Dr. Richard Sikorski has been modeling sea-surface and atmospheric emitted and reflected infrared radiation, for the purpose of simulation of the brightness temperatures (BTs) measured by satellite instruments with various spectral sensitivities, for various atmospheric and marine conditions.

While studying variations in the relative spectral responses (RSRs) of the MODIS thermal IR bands, the impact of these variations on the MODIS error budget was observed to depend greatly on the total vapor and the vertical structure of the simulated atmospheres. To systematically address these dependencies, the radiosonde database has been redesigned. The radiosonde database of vapor/temperature profiles is now being preprocessed into an indexed database of atmospheric optical properties. A broader range of atmospheres are being added to the database. And the spectral range of the model has been extended beyond the original NOAA-9 and NOAA-11 channels to cover the full range of MODIS IR bands.

B.1.2 Algorithm Development Efforts Based on Experimental Match-up Data bases

Focus during this period has been on evaluation of unbiased approaches for parameter estimation. It has been determined that improper attention to cross-correlation effects on multiple regression approaches is a significant issue when dealing with *in situ* sea surface temperature (SST) datasets. Dr. A. Mariano has developed an approach which removes such correlation and improves the quality of the regressed coefficients. Computer runs are in process to validate the approach and determine the stablity of the derived atmospheric correction equations.

B.1.3 The Combined Sensor Cruise of the NOAA ship *Discoverer*

As described in earlier reports the Combined Sensor Cruise in the Tropical Western Pacific in

March–April 1996, generated an unprecedented array of measurements of atmospheric boundary layer and sea surface temperature. The radiometric and in-situ measurements of sea–surface temperature taken by the University of Miami and University of Wisconsin group continue to be analyzed, but this is currently being delayed awaiting the release of air–sea flux measurements taken by other cruise participants.

A publication describing the cruise and the initial scientific results is in preparation, and posters describing the measurements of the skin sea–surface temperature were presented at the AMS Conference on Atmospheric Radiation and at the 7th Atmospheric Radiation Measurements Program Science Team Meeting.

B.1.4 Future validation campaign planning

Space has been offered on the Roger Revelle during a transit from Hawaii to New Zealand in September/October 1997. Plans are going forward to exploit this opportunity as it will provide a M-AERI data set complimentary to that taken in the tropical Western Pacific in spring 1996 (Combined Sensor Cruise - see earlier reports). It will also provide an opportunity to collect radiosonde data in a data-space area of the Pacific Ocean for use in numerical simulations of the MODIS thermal infrared measurements.

The Canadian research agency NSERC has funded the scientific voyages of the Canadian icebreaking research vessel *Louis S. St. Laurent* to the north of Baffin Bay (see report for July-December 1996). Dr. Minnett attended a meeting of the scientists involved in this program in Quebec City, and the offer of berths during one or several of the cruises in 1998 confirmed. Although these cruises will take place before the EOS-AM launch, they will provide an extremely valuable opportunity to test the deployment of the M-AERI and ancillary equipment in an Arctic environment.

Discussions have continued with the US Coast Guard on the potential use of the *USCG-C Polar Sea* on its annual supply voyages from Seattle to Antarctica and return. The prospects of this appear to be very good, but a firm agreement has not yet been offered. Similarly, unofficial approval has been granted of a request to mount the M-AERI on the German ice-breaking research vessel *Polarstern* on a voyage from Germany to Antarctica. Demand for berths is likely to limit the M-AERI deployment to the transit from Germany to Cape Town as the ship is likely to be fully subscribed for the leg from South Africa to Antarctica. The dates tentatively offered are mid-December 1999 to early January 2000.

B.1.5 Meetings at RSMAS

RSMAS hosted two meetings in January 1997: the Thermal Infrared Task Group chaired by Dr. P. Minnett and the MODIS Oceans Group chaired by Dr. W. Esaias of GSFC.

The Thermal Infrared Task Group heard from the MCST about the pre-launch characterization of the thermal infrared channels and discussed the major concerns. These include cross-talk between channels, uncertainties in the spectral response functions of the channels, uncertainties in the specification of the spectral and angular properties of the reflectivity/emissivity of the scan mirror, digitizer non-linearities, etc. A full report was submitted to Dr. V. V. Salomonson soon after the group met.

Another concern of the Task Group is that the construction schedule of the FM-1 instrument is so far advanced that the lessons learned from the PFM tests are not being incorporated into the FM-1, and some of the short-comings are being propagated forward.

The group also discussed post-launch validation efforts and the prospects of co-ordinating these

with the activities of other instrument teams. Dr. Minnett contacted the ASTER and MISR groups. The ASTER team are eager to co-ordinate validation activities.

B.1.6 M-AERI Delivery

Preparations continued with the final construction, testing and software development of the M-AERI-1 at the Space Science and Engineering Center at the University of Wisconsin at Madison. Plans were made for an instrument platform on the roof of the Marine Sciences Center at RSMAS where M-AERI and ancillary instruments can be set up. The M-AERI will have an unobscured view of the water in Biscayne Bay and through a clear horizon to the sky. The ancillary equipment - boundary layer meteorological sensors, broad band radiometers and a radiosonde station have been delivered and tested. Some of the meteorological sensors are mounted on a temporary instrument mast on the roof.

B.1.7 Analyses in support of MODIS infrared channels pre-launch calibration and characterization

In addition to the radiative transfer modeling to simulate the consequences of uncertainties in the spectral characterization of the MODIS infrared channels (see B.1.1), analyses have been conducted to quantify the effects of uncertainties in the instrument properties. These include the dependence of the scan mirror reflectivity, and infrared emissivity, on angle, wavelength and polarization. An analysis has shown that uncertainties in the scan mirror reflectivity of 0.1% can lead to worst case errors in retrieved SST of 0.6K. This is twice the total target uncertainty in SST. Similarly, uncertainties in the scan mirror temperature of >1K would lead to unacceptable errors in the derived SST. Therefore, we feel that a space-based characterization of mirror emissivity is required for adequate algorithm performance. The preferred approach is to view deep-space early in the mission and then annually, thereafter. Such an approach requires an orbital maneuver, which is currently under discussion.

B.1.8 Wide Area Networking

No changes in current configuration. The current configuration of 20+ workstations is being operated on a 7x24 basis. This will provide needed validation prior to shifting of all data processing activities over to ATM.

B.1.7 Documentation

The MODIS Infrared Sea Surface Temperature Algorithm Technical Basis Document (ATBD-MOD-25; available from http://www.rsmas.miami.edu/modis in pdf or ps formats) was revised and presented at the ATBD Review on November 20, 1996. No serious criticisms were raised during the ATBD review process. We have not received the written critique from the review panel. However, we look forward to addressing the panel's concerns.

C. Investigator Support

January	W. Baringer
	O. Brown
	J. Hanafin
	A. Li
	P. Evans
	D. Wilson-Diaz
February	W. Baringer
	O. Brown

	P. Evans
	R. Sikorski
March	W. Baringer
	O. Brown
	G. Goni
	A. Li
	A. Mariano
	P. Minnett
	R. Sikorski
	P. Evans

D. Future Activities

D.1 Current:

D.1.1 Algorithms

a. Continue to develop and test algorithms on global retrievals
b. Evaluation of global data assimilation statistics for SST fields
c. Continue radiative transfer modeling using RAL code
d. Continue analysis of Combined Sensor Cruise, data
e. Continue to study near-surface temperature gradients
f. Continue planning of post-launch validation campaigns.
g. Validation Plan updates (as needed)
h. EOS Science Plan updates (as needed)
i. Define and implement an extended ATM based network test bed
j. Evaluate and analyze results of calibration/validation experiment
k. Continued integration of new workstations into algorithm development environment
l. Continued participation in MODIS Team activities and calibration working group.

D.1.2 Investigator support

Continue current efforts

E. Problems

No new problems to report.

F. Publications and Presentations

Knuteson, R.O., F.A. Best, H.B. Howell, P. Minnett, H.E. Revercomb, and W.L. Smith. High Spectral Resolution Infrared Observations at the Ocean-Atmosphere Interface in the Tropical Western Pacific using a Marine Atmospheric Emitted Radiance Interferometer (M-AERI): Applications to SST Validation and Atmospheric Spectroscopy. Presented at the Ninth Conference on Atmospheric Radiation, 2-7 February 1997, Long Beach, CA.

Minnett, P.J. and R.O. Knuteson. Measurements of the Thermal skin effect and diurnal thermocline in the tropical Pacific Ocean. Presented at the 7th Science Team Meeting of the Atmospheric Radiation Measurements Program, March 1997, San Antonio, TX.